Design of the AGS Upgrade for a Broad Band Neutrino Superbeam

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Abstract. BNL plans to create a very long base line super neutrino beam facility by upgrading the AGS from the current 0.14 MW to 1.0 MW and beyond. The proposed facility consists of two major components. First is a 1.5 GeV superconducting linac to replace the booster as injector for the AGS, second is the performance upgrade of the AGS itself for higher intensity and repetition rate. The major contribution for the higher power is from the increase of the repetition rate of the AGS from 0.3 Hz to 2.5 Hz, with moderate increase from the intensity. The accelerator design considerations to achieve high intensity and low losses for the new linac and the AGS will be presented. The design aspect for high power operation and easy maintenance will also be covered.

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1 INTRODUCTION

The requirements of the proton beam for the super neutrino beam are summarized in Table 1 and a layout of upgraded AGS is shown in Figure 1. Since the present number of protons per fill is already close to the required number, the upgrade focuses on increasing the repetition rate and reducing beam losses (to avoid excessive shielding requirements and to maintain activation of the machine components at workable level). It is also important to preserve all the present capabilities of the AGS, in particular its role as injector to RHIC.

Present injection into the AGS requires the accumulation of four Booster loads in the AGS, which takes about 0.6 sec, and is therefore not suited for high average beam power operation.

TABLE 1. Type Table Name Here.

Total Proton Beam power	1.0	MW
Beam Energy	28	GeV
Average Beam Current	42	μA
Number of Protons per Fill	0.9×10^{14}	
Number of Bunches per Fill	24	
Proton per Bunch	0.4×10^{13}	
Number of Turn for Injection	230	
Repetition Rate	2.5	Hz
Pulse Length	0.72	msec
Chopping Rate	0.75	
Linac Average/Peak Current	20/30	mA

To minimize the injection time to about 1 msec, a 1.5 GeV linac will be used instead. The multi-turn injection from a source of 28 mA and 720 μsec pulse width is sufficient to accumulate 0.9×10^{14} particle per pulse in the AGS. The minimum ramp time of the AGS to full energy is presently 0.5 sec. This must be reduced down to 0.2 sec to reach the required repetition rate of 2.5 Hz to deliver the required 1 MW beam to the target [1].

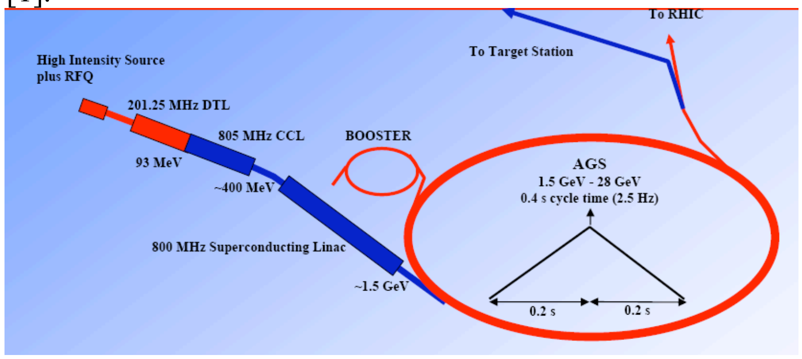

FIGURE 1. Schematic diagram of the accelerators for the neutrino production.

2 SUPERCONDUCTING LINAC

Two modifications are needed for the injector linac: (1) Upgrade the 200 MeV linac to 400 MeV based on the FERMILAB upgrade which was successfully completed in 1993 [2]; (2) Use the SNS high beta cryomodules [3] to 1.5 GeV or higher energies in the 130 meter space.

The beam duty factor for this linac is 4.2 times higher than the FEMILAB upgrade. The proposed solution is to replace last five DTL tank with 10 CCL modules, each having 4 sections with 16 cells per section at lower (1.0 Kilpatrik) filed to reduce the sparking rate. The super conducting linac will consist 15 SNS high beta modules of length 7.891 meters long (including the warm section) which has 4 sections of 6 cells. Assuming an accelerating gradient, E_0T=22 MV/m (achieved for SNS), 15 cyromodules can accelerate H^- from 367 MeV to 1462 MeV. The energy can be upgraded to 1533 MeV if the accelerating gradient (E_0) of 33 MV/m (achieved at TESLA) becomes a reality in future for cavities with $\beta\leq1$. The beam power at 1.5 GeV is only 54 kW, for hand on maintenance loss limit is watt/m, which implies a fractional loss limit of 3 x $10^{-3.}$ The estimated fractional loss is about 1 x 10^{-4}.

3 AGS UPGRADE AND BEAM TRANSFER LINE

In the proposed AGS upgrade for the neutrino beam program, a new 1.5 GeV superconducting linac will be used as injector which can provide 89 x 10^{12} proton with injection time of less than 1 ms. To provide 1 MW beam power for neutrino production, the AGS has to be cycled at 2.5 Hz, instead of 0.5 Hz. For this improved capability, several major upgrades of the AGS have to be implemented: (1) the new direct injection from the SCL with H^- stripping foil system; (2) the new main magnet power supply and its six-loop configuration for the powering of the lattice magnets; (3) the new RF accelerating cavity and its associated power switching system for doubling the accelerating voltage operated at 2.5 Hz; (4) the new single turn fast extraction system for beam delivery to the target; (5) the new collimation and radiation shielding system to keep the beam losses at an acceptable level.

The beam is transported ~ 190 m from the AGS to the U-line spur using present RHIC transfer line magnets. The new beam transport begins at this point. To direct the beam toward the Homestake mine in South Dakota, the beam must be bent 68 degrees, 4 seconds to the west of the U-line direction and 11.26 degrees downward. BNL is located on an aquifer that is the sole-source for Suffolk county drinking water. A beam layout has been developed that takes the beam up and over a 42-meter (beam height) hill to the production target and decay channel. This keeps the target; decay channel and beam dump at or above the present ground level and well above the Long Island water table. Figure 2 shows a 3-dimensional view of this beam transfer line.

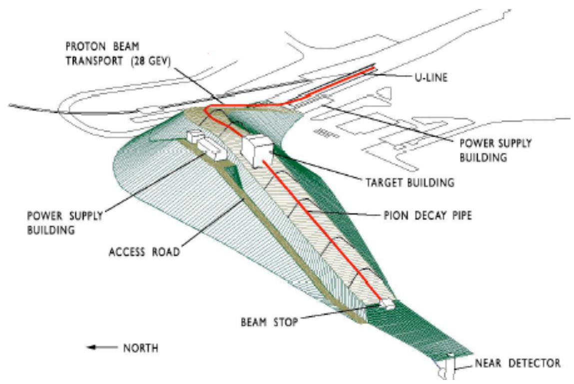

Figure 2: Elevation view of the neutrino beam line to Homestake, South Dakota.

4 CONCLUSIONS

We have produced a design for 1 MW AGS-based neutrino superbeam facility which can be further upgraded to >1 MW by combination of the following improvements 1) increase the AGS intensity to 1.8 X 10^{14} ppp, and 2) increase the AGS rep rate to 5.0 Hz, 3) raise the proton beam energy to 40 GeV and 4) improve on the horn focusing at the target. The associated problem in beam dynamics, power supply, rf system, beam losses and radiation protection are under study and shown to be feasible if such a capability is required by the physics experiments

Several R&D programs in the design of the superconducting cavity and the irradiation testing of target materials are actively pursued to improve on the design.

5 REFERENCE

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